ATMCS11 Schedule

July 2, 2025

Monday, 21 July 2025

Time	Session	Chair
08:30-09:30	Invited Talk 1 – Yusu Wang	Vanessa Robins
09:30-10:30	Invited Talk 2 – Melanie Weber	
10:30-11:00	COFFEE BREAK	
11:00-12:20	Contributed Talks	Tom Needham
	• Halley Fritze	
	• Adam Onus	
	• Andrew M. Thomas	
12:20-13:45	LUNCH	
13:45-14:45	Invited Talk 3 – Amit Patel	Hideto Asashiba
14:45-15:15	BREAK	
17:00	Welcome Reception at AC Hotel (tentative)	

Tuesday, 22 July 2025

Time	Session	Chair
08:30-09:30	Invited Talk 4 – Rocio Gonzalez-Diaz	Amit Patel
09:30-10:30	Invited Talk 5 – Hideto Asashiba	
10:30-11:00	COFFEE BREAK	
11:00-12:20	Contributed Talks	Yusu Wang
	• Manuel Soriano Trigueros	
	• Francisco Martinez Figueroa	
12:20-13:45	LUNCH	
13:45-14:45	Invited Talk 6 – Tom Needham	Melanie Weber
15:00-17:00	Poster Reception	

Wednesday, 25 July 2025

Excursion day.

Thursday, 24 July 2025

Time	Session	Chair
08:30-09:30	Free Time	
09:30-10:30	Invited Talk 7 – Steven Bleiler	Frank Staals
10:30-11:00	COFFEE BREAK	
11:00-12:20	Contributed Talks	Carola Wenk
	• Christopher Fillmore	
	• Florian Russold	
12:20-13:45	LUNCH	
13:45-14:45	Invited Talk 8 – Frank Staals	Ziga Virk
14:45-15:15	BREAK	
15:15-16:35	Contributed Talks	Erin Wolf Chambers
	• Teresa Heiss	
	• Barbara Giunti	
	• Zoe Cooperband	

Friday, 25 July 2025

Time	Session	Chair
08:30-09:30	Invited Talk 9 – Carola Wenk	Rocio Gonzalez-Diaz
09:30-10:30	Invited Talk 10 – Vanessa Robins	
10:30-11:00	COFFEE BREAK	
11:00-12:20	Contributed Talks	Atish Mitra
	• Nicolo Zava	
	• Riley Decker	
12:20-13:45	LUNCH	

Invited Talk 1

Speaker: Yusu Wang, UCSD, `http://yusu.belkin-wang.org/`.

Title: Effective Neural Approximations for Geometric Problems

Abstract: Machine learning, especially the use of neural netowrks, have shown great success in a broad range of applications. In recent years, we have also seen significant advancement in effective neural architectures for learning on more complex data, such as point sets (note that here, each input sample is a set of points) or graphs. Examples include DeepSet, Transformer and Sumformer. This facilitates the development of neural network based approaches to solve (potentially hard) geometric optimization problems, such as the minimum enclosing ball of an input set of points, in a data-driven manner. In this talk, I will describe some of our recent exploration in designing effective neural models for several geometric problems: (1) estimating the Wasserstein distance between two input point sets, and (2) a family of shape fitting problems (e.g, fitting minimal enclosing balls). Our goal is to have a neural network model of bounded size (independent to input size) that can approximately solve a target problem for input of arbitrary sizes. This talk is based on joint work with S. Chen, T. sidiropoulos and O. Ciolli.

Bio: Yusu Wang is Professor in the Halicioglu Data Science Institute (HDSI) at University of California, San Diego, where she also serves as the Director for the NSF National AI Institute TILOS. Prior to joining UCSD, she was Professor in the Computer Science and Engineering Department at the Ohio State University. She obtained her PhD degree from Duke University in 2004 where she received the Best PhD Dissertation Award in the CS Department. From 2004-2005, she was a post-doctoral fellow at Stanford University. Yusu Wang primarily works in geometric and topological data analysis (with a textbook on Computational Topology for Data Anaysis), geometric deep learning, graph learning and neural algorithmic reasoning. She received DOE Early Career Principal Investigator Award in 2006, and NSF Career Award in 2008. She is on the editorial boards for SIAM Journal on Computing (SICOMP) and Journal of Computational Geometry (JoCG). She is on the External Advisory Board of NSF-Simons CosmicAI Institute, as well as the Advisory Committee for AATRN. She was also on the SoCG Steering Committee from 2020-2024. She also serves in the SIGACT CATCS committee and AWM Meetings Committee.

Invited Talk 2

Speaker: Carola Wenk, Tulane, `https://www.cs.tulane.edu/~carola/`.

Title: One-to-one matchings for shape comparison: from persistent homology transform to graph sampling

Abstract: We present recent applications of one-to-one matchings for the comparison of shapes. We start with introducing the kinetic hourglass, a kinetic data structure enabling the efficient computation of the bottleneck distance for dynamic weighted graphs with application to the persistent homology transform. We then study the graph sampling approach, a popular method for comparing road networks, and we show the effect of different matching rules and provide visualizations and a toolkit. We also briefly discuss generalizations of the graph sampling approach to the continues setting, including the length-sensitive Fréchet similarity.

Bio: Carola Wenk is a Professor of Computer Science at Tulane University and the Chair of the Department of Computer Science. She also holds a courtesy appointment in the Mathematics department. Her research area is in computational geometry, with a focus on shape matching algorithms. Her work encompasses theoretical aspects including algorithms and topological data analysis, as well as interdisciplinary applications ranging from geospatial to biomedical data analysis. She is an expert on the Fréchet distance for curves, and her work on map-matching GPS trajectories and road map construction and comparison has laid theoretical foundations for practitioners in the field. Dr. Wenk has won research, teaching, and service awards, including an NSF CAREER award. Her research has been supported by grants from several agencies such as NSF, NIH, DARPA, and IARPA. Her research interests span a wide range of application areas including geospatial data analysis, intelligent transportation systems, geographic information science, biomedical imaging, and computational biology.

Invited Talk 3

Speaker: Amit Patel, CSU, `https://akpatel79.github.io/`

Title: Two Languages, One Invariant: Unifying Möbius Homology and Betti Tables

Abstract: Persistent homology shines in one dimension: filter a space, compute homology, and read off its persistence diagram. This diagram has two equivalent faces. Algebraically, it is the multiset of indecomposable interval summands of the module; combinatorially, it is the Möbius inversion of the module's kernel–rank function on the interval poset.

In higher dimensions the picture splinters and many invariants have been proposed, but two have driven recent activity. One, developed by Patel and Skraba, interprets the data through Möbius homology. The other, developed by Botnan,

Oppermann, Oudot, and Scoccola encodes the same information in Betti tables relative to the rank exact structure. Both yield signed barcodes whose negative entries—appearing in odd homological degrees—have no analogue in the classical setting, yet their precise relationship has remained opaque.

I will show that these two constructions are, in fact, identical. First, I will explain—without heavy prerequisites—how the Möbius homology of a P-module recovers its (standard) Betti tables (i.e., the indecomposable summands in its minimal projective resolution). Then, focusing on persistence, I will prove that the Möbius homology of the kernel module coincides with the relative Betti tables of the original module.

This unification reveals that two seemingly distinct approaches are, in fact, the same—an unexpected convergence that highlights deep structural unity in the theory of multiparameter persistence, and sets the stage for the next big challenges: formulating a satisfactory stability theorem that accommodates negative bars and designing efficient algorithms to compute them.

Joint work with Luis Scoccola; details will appear in an upcoming paper.

Bio: Amit Patel is an Associate Professor of Mathematics at Colorado State University. He is interested in algebraic topology and its applications, and has worked on persistent homology for many years. He received his Ph.D. in Computer Science from Duke University under Herbert Edelsbrunner and has held positions at the Institute for Advanced Study, INRIA, Rutgers, MSRI, and Queen Mary University of London.

Invited Talk 4

Speaker: Hideto Asashiba, Shizuoka, `https://wwp.shizuoka.ac.jp/asashiba/hideto-asashibas-website/`.

Title: Interval Multiplicities of Persistence Modules.

Abstract: For any persistence module M over a finite poset $\mathbf{P}$, and any interval I in $\mathbf{P}$, we give a formula of the multiplicity $d_M(V_I)$ of the interval module V_I in the indecomposable decomposition of M in terms of the difference of the ranks of matrices consisting of structure linear maps of the module M, which gives a generalization of the corresponding formula for 1-dimensional persistence modules. This makes it possible to compute the maximal interval-decomposable direct summand of M, which gives us a way to decide whether M is interval-decomposable or not. Moreover, the formula tells us which morphisms of $\mathbf{P}$ are essential to compute the multiplicity $d_M(V_I)$. This suggests us some poset morphism $\zeta\colon Z \to \mathbf{P}$ such that the induced

restriction functor $R\colon \mathrm{mod}\mathbf{P} \to \mathrm{mod}Z$ has the property that the multiplicity $d := d_{R(M)}(R(V_I))$ is equal to $d_M(V_I)$. In this case, we say that ζ essentially covers I. If Z can be taken as a poset of Dynkin type $\mathbb{A}$, a zigzag poset, as in the bipath case, then the calculation of the multiplicity d can be done more efficiently, starting from the filtration level of topological spaces. Thus this even makes it unnecessary to compute the structure linear maps of M.

Bio: Since April 2021, Dr. Hideto Asashiba is Professor Emeritus at Shizouka University, Researcher at the Institute for Advanced Study, KUIAS, Kyoto University, and Researcher at Osaka Central Advanced Mathematical Institute, Osaka Metropolitan University. From 2007 to 2021, he was a Professor at Shizouka University, and before that he was an Associate Professor at Osaka City University. He earned his Doctor of Science in Mathematics from Osaka City University in March 1984.

Invited Talk 5

Speaker: Tom Needham, FSU, `https://sites.google.com/site/tneedhammath/`.

Title: Variants of Gromov-Wasserstein Distances

Abstract: Gromov-Wasserstein (GW) distances comprise a family of metrics on the space of (isomorphism classes of) metric measure spaces. Driven by specialized applications, there have been a large number of variants of GW distance introduced in the literature in recent years, each of which is designed to provide meaningful comparisons between certain data objects with complex structure. These complex data objects include (attributed) graphs, hypergraphs, point clouds endowed with preferred persistent homology cycles, and many others. In this talk, I will survey some of these variants, focusing on those with connections to applied and computational topology. I will also describe recent joint work with Bauer, Mémoli and Nishino, which introduces a general framework that captures several of these variants, allowing us to derive broadly applicable theoretical properties.

Bio: Tom Needham is an Assistant Professor of Mathematics at Florida State University. Before joining FSU, he earned his Phd in Mathematics at University of Georgia and held a postdoctoral position at The Ohio State University. His research focuses on interactions between topology, geometry and probability and applications of tools from these fields to data science, signal processing and shape analysis.

Invited Talk 6

Speaker: Steven Bleiler, Portland State, `https://www.pdx.edu/faculty-experts/expert/steven-bleiler`.

Title: Novel visualizations of quantum operations via toral geometry.

Abstract: Complex projective spaces have long been familiar to topologists and geometers, who over the years have developed several ways of visualizing and interpreting these spaces. As appropriate for the mathematical analyses at hand. For example, familiar to just about all students of algebraic topology, if not so much to the physicists and engineers, is the cell decomposition of CP^n with a single cell in each even dimension attached to the previous cell lower of even dimensional by what is essentially the quotient map of the (right hand) Hopf fibration. Less familiar, even among mathema/cians, is the expression, as ini/ally given by F. Hirzebruch in the 1950's, of these spaces as toric varieties, carrying an equivalent toral geometry that arises as the collection of orbits of a smooth action of the n-torus, Tn, considered as the n-fold product with itself of the first unitary group, U(1), consisting of the unit complex numbers. For the complex projective spaces then we have a decomposition of the space into subsets isomorphic to tori of various dimensions (including the "degenerate" tori T0, consisting of a single point, and T1 consisting of a single copy of U(1)) indexed by a "manifold with corners", which in the case of the complex projective space CP^n is just the standard n-simplex Dn

In hindsight, this situation is somewhat surprising as the axioms of quantum mechanics establish these various complex projective spaces as the state spaces of the fundamental quantum logical units used in quantum computation and the toral geometric structure on these spaces is the exact structure on these spaces induced by the measurement axiom of quantum mechanics. Visualizations of this toral geometric structure thus allows for the development of visual predic/ve models for the actions of quantum operations on the state spaces of these fundamental logical units. The recent advent of topological quantum computation has brought a focus on the state spaces of ternary and other higher dimensional logic units, e.g. the quantum trits and quantum quadits, the latter of which have state spaces identical to that of the joint state space of a pair of quantum bits and where the phenomena of separability and entanglement arise for the first time. To mathematicians, these are the complex projective spaces CP^2 and CP^3. Recently certain quantum computer engineers have been exploiting the toral geometric structure on the Bloch sphere CP^1 to discover "new" visualizations of physical operations (what they call "gates") on the state spaces of quantum bits, thus allowing the design of new, more efficient "naive" quantum gates for the various implementations of quantum computation

under development by such players as IBM and Intel; and are now moving to the higher dimensional spaces CP^2 and CP^3 to perform similar tasks for say, the ternary logic commonly found in anyonic topological quantum computation, as developed by Microsoft.

In this talk we'll present, in an "elementary "way, the toral geometric structures on $\mathrm{CP}^{\{1,2,and\,3\}}$, and show how they can be used to "visualize" various quantum phenomena and the actions of various well and not so well-known quantum gates. No previous quantum mechanical experience required.

Bio: Originally trained in classical knot and 3-manifold theory, Steve is a pure and applied mathematician with broad and varied interests and published research record, ranging from the geometry of music to the quantization of poker. In addition to working with mathematical colleagues across the discipline, he also collaborates with engineers, computer scientists, economists, financiers, physicists and chemists. Steve served the regional mathematical community for well over three decades as a founder and as project director for the Cascade Topology Seminar, and continues to serve the mathematical and broader community as a sought after speaker for both popular and technical audiences, by performing frequent peer reviews for several well respected journals, and through review panel service for various private and governmental granting institutions.

Invited Talk 7

Speaker: Rocio Gonzalez-Diaz, Sevilla, `https://personal.us.es/rogodi/personal.html`.

Title: Induced Persistence Matchings: New Tools for Topological Data Analysis and Beyond

Abstract: Understanding and comparing persistence modules via persistence morphisms remains a major challenge in topological data analysis. In this talk, I will present a series of recent advances on matchings between persistence diagrams induced by morphisms, introducing powerful new tools that bridge algebra, topology, and data science. We begin by exploring block functions associated with persistence morphisms, highlighting their algebraic structure and efficient computation via matrix operations. Building on this foundation, I will introduce induced persistence matching diagrams — stable and interpretable features that can assess, for example, the topological quality of subsets within larger datasets, offering new insights into the reliability of data selections for machine learning. Next, I will present the induced matching distance, a novel topological metric, along with its application to robotics,

where it helps distinguish evolving agent behaviors through coherent group tracking. Finally, I will discuss key properties and stability results associated with these new tools. Altogether, these contributions demonstrate how matching-based structures enrich the classical persistence framework, opening new directions for applications in machine learning, robotics, and beyond.

Bio: I got my doctorate in 2000 in the area of Combinatorial Algebraic Topology. In 2005, I published papers in the context of Simplicial Topology and Homological Perturbation Theory. The paper "On the cohomology of 3D digital images" published in 2005 was awarded for being the most cited article in the Discret. Appl. Math. journal during the years 2005-2010. In 2008, I started a very fruitful collaboration with the Pattern Recognition and Image Processing group led by Prof W Kropastch (TUWien, Austria). That year, I was invited as a 'guest professor' and we published the paper "Invariant representative cocycles of cohomology generators using irregular graph pyramids" in a JCR Q1 journal. In 2010, I founded the Andalusian group FQM 396: 'Combinatorial image analysis' for which I have been responsible since then. Following the codirection of the 2013 International DGCI congress in Seville. From 2011 to 2015 we had a fruitful collaboration with researchers from CENATAV (Cuba) in topological gait recognition. I have been the principal researcher of several national projects related to computational algebraic Topology and its applications to computer vision and machine learning. I have consolidated collaborations with several research groups in the United States, Austria, China, France, Italy, and Cuba, making stays through contracts with the university of destination, publishing in high-impact journals. In 2022, I was promoted to Full Professor. Thanks to the results recently obtained in the relationship between topology and neural networks, we were awarded 2023 funding for the EU project 'REliable & eXplAinableSwarm Intelligence for People with Reduced mObility'. Recently, my research has expanded into Green and Interpretable AI, focusing on efficient deep learning through topological methods.

Invited Talk 8

Speaker: Frank Staals, Utrecht, `https://fstaals.net/`.

Title: Analyzing entities moving in a geometric environment.

Abstract: In many movement analysis tasks the entities under study (e.g. people, objects such as robots, or animals) actually move in an environment that constrains their movement. While there is a growing body of work that analyzes moving entities, this analysis often assumes the entities are simply moving in an "empty" space, e.g. R^d. By incorporating the environment, e.g. as a polygonal domain, we can more

accurately perform movement analysis tasks. However, this does pose additional challenges that yield interesting computational problems. In the talk I will explain some of these challenges, and show some techniques we can use to overcome them.

Bio: I am currently working as an assistant professor in the Department of Information and Computing Sciences at Utrecht University. In the past, I was a PostDoc at MADALGO, the center for massive data algorithmics, in Aarhus. I obtained my PhD at Utrecht University, and I studied Computer Science at the TU Eindhoven. My main research area is in Computational Geometry, an area that focuses on the development of algorithms dealing with geometric data such as points, lines, and circles. I am particularly interested in problems involving objects that move, geometric data structures, and shortest-paths. My main aim is to develop solutions that provably correct and efficient. Although my work is typically theoretical in nature, I do really like it if problems have a real-world application, for example in areas such as Geographic Information Science and Visualization.

Invited Talk 9

Speaker: Melanie Weber, Harvard, `https://melanie-weber.com/`.

Title: A Geometric Lens on Challenges in Graph Machine Learning: Insights and Remedies.

Abstract: Graph Neural Networks (GNNs) are a popular architecture for learning on graphs. While they achieved notable success in areas such as biochemistry, drug discovery, and material sciences, GNNs are not without challenges: Deeper GNNs exhibit instability due to the convergence of node representations (oversmoothing), which can reduce their effectiveness in learning long-range dependencies that are often crucial in applications. In addition, GNNs have limited expressivity in that there are fundamental function classes that they cannot learn. In this talk we will discuss both challenges from a geometric perspective. We propose and study unitary graph convolutions, which allow for deeper networks that provably avoid oversmoothing during training. Our experimental results confirm that Unitary GNNs achieve competitive performance on benchmark datasets. An effective remedy for limited expressivity are encodings, which augment the input graph with additional structural information. We propose novel encodings based on discrete Ricci curvature, which lead to significant gains in expressivity, as well as in empirical performance thanks to capturing higher-order relational information. As part of this discussion, we will also provide rationale for the use of curvature in graph-based geometric data analysis, by presenting discrete-to-continuum consistency results which show that discrete Ricci curvature can provably characterize the geometry of a manifold based on a finite sample.

Bio: Melanie is an Assistant Professor of Applied Mathematics and of Computer Science at Harvard University, where she leads the Geometric Machine Learning Group. Her research studies geometric structure in data and how to leverage such information for the design of new, efficient Machine Learning algorithms with provable guarantees. In 2021-2022, she was a Hooke Research Fellow at the Mathematical Institute in Oxford. Previously, she received her PhD from Princeton University (2021), held visiting positions at MIT and the Simons Institute in Berkeley, and interned in the research labs of Facebook, Google and Microsoft. She is a recipient of the IMA Leslie Fox Prize in Numerical Analysis (2023) and a Sloan Research Fellowship in Mathematics (2024).

Invited Talk 10

Speaker: Vanessa Robins, ANU, `https://physics.anu.edu.au/contact/people/profile.php?ID=75`.

Title: Topological image analysis: fundamentals and applications.

Abstract: Digital images are a ubiquitous form of scientific data and there are countless methods for processing and extracting quantitative information from them. This talk will outline some persistent homology-based approaches I've used to quantify geometric structure in 2D and 3D digital images, hopefully clarifying the topological foundations required for working with scalar functions defined on regular grids, name-dropping a few key algorithms, and illustrating results with some real-world data.

The first challenge in working with digital images is understanding the topological ambiguity of cubical grids. This means that the two main approaches for converting a grayscale image to a function defined on a cell complex: the "top" and "vertex" constructions can yield different persistent homology for the same input. I'll describe a simple algorithm to translate sublevel set persistence diagrams between these two settings.

My work with digital images started with the challenge of analysing the geometry and connectivity of porous materials from x-ray CT data. This led to the "ProcessLowerStar" algorithm and methods to compute sublevel set persistent homology based on discrete Morse theory. The standard processing steps used in this application include segmenting the original x-ray image into two domains, "pore" and "solid", then computing the distance from each grid point to the boundary between

the two domains. The “signed distance function” assigns distances in the pore region to be negative, and those in the solid positive. Sublevel set persistence diagrams of these signed distance functions provide a rich geometric signature of both pore and solid domains. I’ll describe recent work studying the stability (or otherwise) of these signed distance functions with respect to changes in segmentation thresholds.

Another approach to quantifying shape from segmented images uses height filtrations and the persistent homology transform (or its extended version). I’ll illustrate how this geometric summary facilitates clustering within families of shapes including preliminary results from a current project working with CT images of lungs.

Bio: As/Pr Vanessa Robins, (BSc Hons 1994, PhD 2000 in Applied Mathematics), is Associate Professor in the Research School of Physics at the ANU. Her contributions to topological data analysis include early foundations for persistent homology, algorithms and software development for computing persistence diagrams from 2D and 3D digital images. She has contributed to over 50 publications with over 50 co-authors, spanning various disciplines including soft matter, crystallography, geo-engineering, theoretical physics, computer science, pure and applied mathematics.